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DaimlerChrysler AG
Stuttgart

Method and apparatus for determining the adhesion and adhesion limit in the case of vehicle tyres

The invention relates to a method and an apparatus for determining the adhesion and/or adhesion limit of a tyre of a vehicle in motion. In this method and apparatus, the driving state of the vehicle is measured by means of a plurality of driving-dynamics sensors, and the state of the roadway is determined by means of at least one roadway sensor, which detects the state of the roadway. A computer for evaluating the data from the driving-dynamics sensors and the roadway sensor is furthermore provided, the said computer using a driving-dynamics simulation model to determine the kinematic state of the wheel and the adhesion or, taking into account at least one stored tyre characteristic diagram comprising tyre characteristics, the adhesion limit.

If a vehicle fitted with tyres is in a normal driving state involving comparatively low longitudinal and transverse acceleration values, i.e. not in the region of the driving limit, it has hitherto been impossible to draw reliable conclusions about the adhesion and adhesion limit of tyres or wheels, of axles or of the vehicle. There is a large degree of uncertainty as to the size of the adhesion reserves, i.e. the gap between the current horizontal forces (circumferential forces and lateral forces) between the tyre and the roadway (the adhesion) and the maximum forces that can be transmitted (the adhesion limit).

In a normal driving state involving comparatively low longitudinal and transverse acceleration values, it has hitherto only been possible to estimate the adhesion and adhesion limit of production vehicles qualitatively on

the basis of the driver's experience, and this only very roughly. With this in mind, the driver can, for example, observe that the roadway is wet and instinctively assume a reduction in the adhesion limit compared with a dry roadway on the basis of his experience. However, this is only partially successful, as demonstrated by the increase in the frequency of accidents on wet roads. On production vehicles, there has hitherto been no facility for determining the adhesion and adhesion limit quantitatively at low longitudinal and transverse accelerations.

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It has hitherto also been impossible to provide reliable information on the adhesion and adhesion limit as the vehicle approaches the driving limit, i.e. the adhesion limit, where the longitudinal and transverse acceleration values are comparitively higher. On production vehicles there are known systems such as ABS, ASR or ESP which detect when the vehicle is reaching an adhesion limit or a limit in terms of driving dynamics. However, the adhesion and the adhesion limit are determined neither while the vehicle is in a normal driving state nor as it approaches the driving limit.

In the literature reference H.-J. Görich, System zur Ermittlung des aktuellen Kraftschlußpotentials eines PKW im Fahrbetrieb [System for determining the current adhesion potential of a moving passenger car], Fortschritt-Berichte VDI Series 12, No. 181, VDI-Verlag 1993, Düsseldorf, a proposal is made for a system which allows the adhesion and adhesion limit to be estimated in many cases. Here, driving-dynamics sensors supply information on the driving state. Roadway sensors, each of which is responsible exclusively for a specific roadway, furthermore supply information on the state of the roadway. In addition, extensive measurements incorporated into tyre characteristic maps are required

for various states of the roadway. Using a simple though not particularly quick vehicle computation model and a vehicle computer which does not allow real-time operation, the current driving state, i.e. the adhesion of the axles and of the vehicle, is compared with the vehicle's adhesion limit determined. The results for the vehicle are represented graphically using a screen in the vehicle.

Although the known system supplies information on the adhesion and the adhesion limit of the vehicle, it has various disadvantages.

One disadvantage is that extensive tyre characteristic maps comprising a multiplicity of tyre characteristics for all conceivable driving states and states of the roadway are required. These tyre characteristics are assumed to be invariable. This leads to the results becoming inaccurate as the tread depth decreases during the operation of the vehicle, for example.

In addition, there is the fact that the states of the roadway are divided only relatively roughly into three groups, namely dry, wet and slippery (as in winter). Within a group, the tyre characteristic maps are assumed to be constant. This likewise leads to, in some cases, very inaccurate results since it is known that, in reality, the depth of water on a wet roadway has a great effect, for example. It is furthermore disadvantageous that the adhesion is determined only for each axle and the adhesion and the adhesion limit are determined for the vehicle. This likewise leads to inaccuracies in determination, especially when the wheels are rolling on different underlying roadway surfaces. There is thus no possibility of calculating the adhesion separately for each individual wheel.

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In the literature reference Th. Dieckmann, Ein neuartiger Ansatz zur Bestimmung der Kraftschlußbedingungen im Reifen/Fahrbahnkontakt, Reifen, Fahrwerk, Fahrbahn [A novel approach to the determination of adhesion conditions in tyre/road contact, tyres, running gear, roadway], Report on the conference of the VDI-Gesellschaft Fahrzeugtechnik, No. 916, VDI-Verlag, 1991, Düsseldorf, and in document DE 3705983 A1 ("Device for monitoring the utilization factor of the coefficient of road friction prevailing in the braking and/or acceleration of a motor vehicle"), a proposal is made for a method in which conclusions are drawn about the maxima of the circumferential forces that can be transmitted from the initial slope of the circumferential-force/slip curves of the wheels and in which conclusions are drawn therefrom about the adhesion and the adhesion limit of the entire vehicle. This principle is relatively inaccurate and has the following disadvantages.

On the one hand, only the circumferential-force properties of the tyres are taken into account, allowing only limited conclusions to be drawn about the lateral-force properties.

It has furthermore been found that a sufficiently clear change in the initial slope cannot be recognized in all cases required in practice. Thus, for example, a large difference between the adhesion limits is possible during the transition from a dry roadway to a wet roadway with shallow or moderate water levels, whereas the initial slopes differ only to a small extent.

It is furthermore known that the initial slope of the circumferential-force/slip curves depends not only on the state of the roadway but also on the properties of the tyres, which change, for example, due to a decrease in the tread depth. Since the stored characteristics are

fixed and do not take into account changes in the tyre properties during operation, it is not possible to draw reliable conclusions about the current adhesion limit from the initial slope.

In document DE 4338587 C2 ("Method for estimating gripping properties of road surface with respect to the wheels of a motor vehicle travelling over it"), the proposal is to measure the torque of the driven wheels and the rotational speed of all the wheels. Moreover, the wheel load acting on the driven wheels is estimated. When the driven wheels reach certain circumferential-slip values and approach the adhesion limit, the current adhesion of the wheels is set to equal the current adhesion limit of the wheels. This is stored in a memory as an instantaneous but temporary estimated value. This stored estimated value is updated as soon as certain conditions are present, if, for example, a driving state involving high circumferential-slip values, in which the adhesion of the wheels is different, is reached again. In this way, the adhesion and adhesion limit of wheels is determined, and it is possible to draw conclusions about the adhesion and adhesion limit of the vehicle.

However, this proposed principle has the disadvantage that sufficiently accurate estimation is only possible if the vehicle comes within the immediate vicinity of the driving limit. In normal driving states, determination cannot be carried out.

The stored adhesion limits can furthermore only be updated if certain criteria, e.g. high circumferential-slip values, are met. Since this is the case only in infrequent driving states, the stored values cannot be updated continuously and thus reliably, despite continuous operation of the system.

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According to this document, provision is furthermore made for the torque acting on the driven wheels to be measured. This measurement is relatively involved and must operate equally during braking and acceleration. There is furthermore the fact that only the adhesion limit of the tyres is estimated, without information on the shape of the full tyre characteristic being supplied.

The prior art furthermore includes systems which have been investigated within the context of research projects. They allow either only qualitative verdicts on the adhesion and the adhesion limit or, to detect the state of the roadway, require complex sensors which are unsuitable for practical applications or involve unacceptably high costs if used on production vehicles.

Taking this prior art as a starting point, the object on which the invention is based is to provide a method and an apparatus by means of which, as a good approximation, the current adhesion and/or the current adhesion limit of a tyre or of axles of a moving vehicle can be determined in as far as possible every driving state, that is to say even at comparatively low longitudinal and transverse acceleration values. It should thus be possible to determine the current adhesion limit well before it has been reached. It is furthermore desirable if the associated tyre characteristic maps can be prepared for a comparatively low outlay.

The invention is thus intended to provide reliable and accurate information on the current adhesion or current adhesion limit in a manner which allows as little outlay as possible. This information can then be made available to the driver, for example, or passed to a system which performs a control intervention in a driving or braking operation.

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To achieve this object in the case of a method and an apparatus of the type stated at the outset, the invention provides for the tyre characteristics (for various states of the roadway and, for example, for various wheel loads) to be adapted to the current tyre behaviour in the course of operation, starting from an initial set of basic tyre characteristics.

In the method according to the invention, the current adhesion, in particular the circumferential and lateral forces, and the kinematic state of the wheel, in particular the circumferential-slip and slip angle, are calculated continuously with the aid of the computer, the driving-dynamics simulation model and the signals of the driving-dynamics sensors. The current adhesion limit is furthermore determined by first of all carrying out roadway detection and then selecting associated tyre characteristics (e.g. for various wheel loads) from a tyre characteristic-map memory and, finally, after tyre-characteristic adaptation, determining the current adhesion limit.

In this method, the driving-dynamics sensors supply measurement data about the kinematic state of the vehicle and, possibly, about the forces or moments acting on the vehicle. They are used as input variables for the simulation calculations of the computer by means of the driving-dynamics simulation model. The output variables supplied by the simulation calculations are the current adhesion and the kinematic state of the wheels. These variables constitute output data from the system and can also be used for determining the current adhesion limit.

In principle, the state of the roadway (e.g. dry, wet, snow etc.) can be determined in a manner known per se by means of one or more roadway sensors. However, one disadvantage with this is that the decision as to which

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state of the roadway is present depends in each case on the correct and reliable operation of a particular specific sensor for the respective state of the roadway or on a particular evaluation variable. If one sensor is malfunctioning or an evaluation variable is incorrect, the corresponding roadway can therefore no longer be identified.

In order to ensure accuracy of determination, the state of the roadway should be detected accurately and reliably. For this purpose, it is proposed, in accordance with a preferred additional feature, that the state of the roadway is determined by means of a plurality of different roadway sensors, the information derived from their signals being evaluated by means of a bound method for delimiting the state of the roadway. In addition to the information on the state of the roadway determined by the roadway sensors, it is also possible for results from the driving-dynamics simulation calculation to be evaluated in the bound method. One example of a piece of information that can be taken into account in the bound method is, for instance, the initial slope of the actual adhesion curve, which can be determined by means of the driving-dynamics simulation calculation.

In the bound method, a multiplicity of pieces of information of different kinds is superimposed, allowing particular states of the roadway to be excluded on the basis of existing combinations of sensor signals or other information, the correct state of the roadway thus finally being identified as the result of logical combination of the existing information. This is not to be confused with a system incorporating a redundant arrangement of roadway sensors, in which a number of different sensors are intended to sense the same state of the roadway independently of one another. In the bound method that is advantageously employed, different pieces

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of information are collected and the state of the roadway is inferred by combination of these pieces of information.

If the state of the roadway has been determined by means of the bound method, for example, the associated tyre characteristic diagram (comprising characteristics for various wheel loads for example) or the associated tyre characteristic can be selected from a tyre characteristic-map memory. Selection can be assisted by information from the driving-dynamics sensors. When an apparatus according to the invention is first put into operation, a basic tyre characteristic diagram containing an initial set of basic tyre characteristics stored in the computer for a small number of different tyre/roadway combinations is taken as a starting point.

In the course of the operation of the vehicle, these basic tyre characteristics are adapted to the current tyre behaviour by correcting the individual characteristics. This is possible because the system is constructed in such a way that it detects a change in the adhesion behaviour due to a change in tyre properties, e.g. due to a change in tread depth, in the course of operation from the fact that, in this case, the current adhesion and the kinematic state of the wheels do not match the selected characteristic diagram or the selected characteristic. The correction can be repeated each time a deviation is detected.

The adaptation of the tyre characteristics can thus preferably take place when a deviation in the current adhesion in the existing kinematic state of the wheel from the selected tyre characteristic is detected on the basis of a comparison between the results of the driving-dynamics simulation model and the state of the roadway determined.

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The basic tyre characteristic maps or the tyre characteristic maps preferably contain only a small total number of tyre characteristics (for various states of the roadway and, for example, various wheel loads) to be taken into account in the driving-dynamics simulation calculation, preferably fewer than 40, particularly preferably fewer than 20 tyre characteristics. In accordance with an additional advantageous feature, however, provision can be made for one or more tyre characteristic maps to be supplemented in the course of operation by tyre characteristics for further states of the roadway which were not included in the basic tyre characteristic maps and have proven useful. To this extent, the system can be capable of learning and can be designed to be adaptive.

If it is the case both that the current state of the roadway has been identified and the associated tyre characteristic has been selected by the system and adapted to the current tyre behaviour, the adhesion limit can be determined before it has been reached. Using the method according to the invention, it is thus possible to determine the adhesion and adhesion limit more accurately than was hitherto possible. One advantage of the preferred bound method is that the state of the roadway can be detected more reliably, redundant detection being possible.

In a preferred embodiment of the invention, it is furthermore advantageous that a change in the adhesion behaviour caused by a change in tyre properties, e.g. by the change in tread depth, in the course of operation can be detected. In addition, only a small number of basic tyre characteristic maps or basic tyre characteristics is required and these can be adapted and, if appropriate, supplemented in the course of operation.

According to another advantageous feature, it is proposed that the driving-dynamics simulation model is a real-time model, by means of which the computer calculates the current kinematic state of the wheel and/or the current adhesion and/or the current adhesion limit of the wheel in real time. A driving-dynamics simulation model of this kind, which operates in real time, can be created, for example, by means of rapid, compact differential equations using knowledge on the dynamic behaviour of the vehicle concerned.

If the driving-dynamics simulation model used is designed specifically for real time, the current adhesion calculated in real time using this model and the kinematic state of the wheels can advantageously be used as an input variable for a mechatronic control system which performs control interventions in the handling. If the current adhesion is calculated separately for each wheel, the results can be used, for example, for optimized control of the driving dynamics, thereby making it possible to better ensure the stability of the vehicle in critical driving situations.

These data can also be used in an advantageous manner by mechatronic control systems through determination of the adhesion limit in real time. In this case, for example, a mechatronic brake system can respond more rapidly to changing roadway grip in the event of full braking. If the adhesion limit is determined individually for each wheel, a difference in the grip for the wheels of one axle can be taken into account even as a braking operation is being initiated.

The adhesion and/or the adhesion limit is/are therefore preferably determined for the individual wheels of the vehicle or separately for the wheels of an axle since the kinematic state and critical driving behaviour can

thereby be detected more accurately. This provides favourable preconditions for a system which, for example, gives the driver a warning or performs a control intervention in the handling. Determining the adhesion limit separately for individual wheels makes it possible to estimate more accurately whether, owing to different adhesion limits at the individual wheels, critical handling behaviour of the vehicle is to be expected when the vehicle is approaching the driving limit. In this case, it is possible, for example, for a warning to be issued to the driver while the vehicle is still a relatively long way from the driving limit. In the case of individual calculation or evaluation of the wheels of an axle, it is also possible to detect and take account of the case where the wheels have different friction coefficients due, for example, to differences in the state of the roadway.

However, in many embodiments it can also be advantageous if the adhesion and/or the adhesion limit is/are determined for each axle, the wheels of an axle being treated equally, or if the adhesion and/or adhesion limit of the entire vehicle is determined by means of the particular adhesion values and/or adhesion limits of all the wheels. Calculating the adhesion or adhesion limit of the entire vehicle is suitable for allowing the driving state or driving limit of the vehicle to be described in a simple and easily comprehensible manner. The driver can, for example, be informed during the journey using a suitable representation of the adhesion or adhesion limit.

Within the context of the present invention, it has surprisingly been found that the extremely difficult requirements involved in determining the adhesion or adhesion limit of a tyre with sufficient accuracy can be met for a relatively low outlay without the need for a

high technical outlay involved in providing a multiplicity of tyre characteristic maps or of tyre characteristics or for the determination of the state of the roadway, as was previously thought necessary. The invention thus achieves aims which have long been pursued by those skilled in the art.

In order at the same time to achieve particularly good results, the features explained above and the features of the exemplary embodiments below can advantageously be employed singly or in combination, and additional advantageous effects may be obtained from the interaction of features according to the invention.

The invention will be explained in greater detail below with reference to exemplary embodiments, which are illustrated schematically in the figures and which reveal further following features and characteristics.

In the drawings:

Fig. 1 shows a diagram of the method for detecting the adhesion and the adhesion limit,

Fig. 2 shows a bound method for determining the state of the roadway,

Fig. 3 shows a tyre characteristic diagram including five tyre characteristics and

Fig. 4 shows high-precision adaptation of a tyre characteristic.

As regards the meaning of the terms used in the text of this application, attention is drawn to the following supplementary literature: DIN 70000; DIN 44300; J. Reimpell-K. Hoseus, Fahrwerktechnik: Fahrzeugmechanik [Suspension technology: Vehicle mechanics], Vogel Buchverlag 1992; A. Zomotor, Fahrwerktechnik: Fahrverhalten [Suspension technology: Handling], Vogel Buchverlag 1991. Although some of the terms used in these

literature references differ from one another slightly, the person skilled in the art will be able to allocate the correct meaning to them without difficulty.

Fig. 1 shows a flow diagram intended to illustrate more specifically the mode of operation of a system according to the invention for determining the adhesion and the adhesion limit for each individual wheel of a vehicle. The word "adhesion" is here intended to denote the resultant of the circumferential force and the lateral force acting on the wheel, i.e. the adhesion is described by two forces or their resultants. The term "adhesion limit" is intended to denote the maximum possible circumferential force and lateral force which can be transmitted in the current driving state and with the current roadway surface. The adhesion limit is thus described by two forces.

In this context, the circumferential force is the component of the ground reaction force in the direction of the X_W axis (DIN 70000), i.e. obviously the force (motive or braking force) in the longitudinal direction of the wheel in the centre plane of the rim and in the plane of the roadway. The lateral force is the component of the ground reaction force in the direction of the Y_W axis (DIN 70000), i.e. obviously the force transverse to the wheel, perpendicular to the longitudinal direction of the wheel, in the plane of the roadway.

The system illustrated schematically in Fig. 1 performs two main tasks. The left-hand part of the flow diagram shows system components used to calculate the current adhesion. The right-hand part shows the system components by means of which the current adhesion limit is determined before this limit is reached. However, the adhesion limit is not determined independently of the adhesion. There is data exchange between the left-hand

part and the right-hand part.

The system comprises two groups of sensors. One group comprises driving-dynamics sensors 1, which supply data on the state of the vehicle as regards its driving dynamics. The other group comprises roadway sensors 2, which supply data on the state of the roadway.

The driving-dynamics sensors 1, some of which may already have been fitted as standard in the motor vehicle, supply, for example, measurement data on the longitudinal acceleration of the vehicle, the transverse acceleration, the roll angle, the pitch angle, the yaw angle, the rotational speeds of the individual wheels and the wheel loads of the individual wheels.

It is also possible to determine individual variables indirectly, rather than measuring them directly. In general terms, it is possible to include in the method driving-dynamics variables derived from data measured by means of the driving-dynamics sensors. For example, it is possible for the yaw angle to be determined by integrating the measured yaw rate or for the wheel load to be determined indirectly by measuring the compression travel of the wheels relative to the body rather than measuring the wheel load. It is also possible, for example, for measurement of the wheel loads of the wheels of an axle to be replaced by measurement of the axle load, which is apportioned to the individual wheels using data from the driving-dynamics sensors 1, in particular the roll angle.

It is also possible, for example, for measurement of the wheel loads to be replaced by determination of the total weight. The total weight can be determined, for example, by measuring the drive torques and using the measurement signals of the acceleration sensor in the longitudinal

direction. In this case, it is possible, using data from the driving-dynamics sensors 1, in particular the pitch angle, to perform apportioning to the axle loads and, in particular by means of the roll angle, to perform apportioning to the individual wheel loads.

The data from the driving-dynamics sensors 1 and variables which may, if appropriate, have been derived indirectly therefrom are passed to the driving-dynamics simulation model 3, which is advantageously operated in real time. Real-time systems are distinguished by the fact that they can process external events within a predetermined time and thus comply with the external time conditions (DIN 44300). This means that, in real-time simulation, the calculated dynamic phenomenon corresponds at every point in time to the phenomenon which has actually occurred. There is no significant delay separating the behaviour of the real-time system from the behaviour of the real system.

Using the driving-dynamics simulation model 3, the circumferential forces currently acting on the individual wheels, the circumferential-slip values, the lateral forces and the slip angle are calculated. The term "circumferential slip" is here taken to mean the variable $S_{x,w}$ in accordance with DIN 70000, which clearly describes the slip between the tyre and the roadway that occurs during braking or propulsion since, for the same vehicle speed, the wheel rotates more slowly during braking and more rapidly during propulsion than in the free-rolling state. According to DIN 70000, the slip angle is the angle between the X_w axis and the tangent to the curve of the path of the wheel contact point and describes clearly the angle between the longitudinal direction of the wheel and the vector for the rate of travel of the centre of gravity of the wheel.

As the output variable, the driving-dynamics simulation model 3 supplies the current adhesion 4 for the individual wheels. The output data of the driving-dynamics simulation model 3 including the following variables - longitudinal acceleration, transverse acceleration, roll angle, pitch angle, yaw angle, rotational speeds of the wheels and wheel loads - are also passed to the roadway detection component 5 and the characteristic adaptation component 6.

The roadway sensors 2 supply data on the temperature of the roadway and/or on the state of the roadway, for example, using optical or acoustic methods for example. It is also possible to employ sensors which give only a yes/no output, as to whether the roadway is dry or not for example.

The data from the roadway sensors 2 are processed by the roadway detector 5, which also receives results from the calculations by the driving-dynamics simulation model 3. These results of calculation are used for roadway detection if the current operating points in the tyre characteristic are in the linear range of the circumferential-force/slip and lateral-force/slip-angle curves, i.e. if the vehicle is travelling with comparatively low longitudinal and transverse acceleration. Using the current operating points, it is possible in this case to determine the initial slope of the circumferential-force/slip and/or the lateral-force/slip-angle characteristic under consideration. In DIN 70000, the slope of the circumferential-force/slip curve is referred to as the circumferential-force/circumferential-slip gradient. The initial slope of the circumferential-force/slip curve is equivalent to the circumferential-force/circumferential-slip gradient at the circumferential force 0.

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These initial slopes and data on the temperature of the roadway and the state of the roadway are thus available by optical or acoustic methods to allow the state of the roadway to be determined. The state of the roadway can then be identified using a bound method. Since there is at least partial redundancy in the identification of the state of the roadway, it is possible in many cases to carry out a plausibility check. If, for example, a large depth of water has been identified on the basis of the optical or acoustic methods, the temperature of the roadway should not simultaneously be very low. If this is nevertheless the case, it can be concluded from this that the roadway detector is faulty, and the system is switched off. As an alternative, there is also the possibility of giving certain signals priority, the system thus remaining active and merely outputting a fault message.

If the roadway detector 5 is operating correctly, the state of the roadway determined is passed to a characteristic-map memory 7, preferably separately for each wheel. The characteristic-map memory 7 furthermore receives information from the driving-dynamics sensors 1, in particular on the wheel load of the wheel for the selection of the appropriate tyre characteristic.

To increase accuracy, further parameters can be taken into account, e.g. the influence of the camber angle. Since this is generally not measured in vehicles, it is possible to use a substitute dependency on a measured variable or on a combination of measured variables, e.g. wheel load and transverse acceleration. Finally, the information from the roadway detector 5 and the driving-dynamics sensors 1 are used to select a suitable tyre characteristic diagram (for different wheel loads, for example) and, from this, a suitable tyre characteristic, preferably for each individual wheel separately.

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The selected tyre characteristic (or a tyre characteristic diagram) is passed to the characteristic adaptor 6. Since the characteristic adaptor 6 also receives the output data from the driving-dynamics simulation model 3, it is possible to check whether the current adhesion 4 and the kinematic state of the individual wheels matches the selected tyre characteristic. If this is not the case, the tyre characteristic or the tyre characteristic diagram is corrected by adapting individual characteristics, which are stored in the characteristic-map memory 7.

However, the adaptation does not have to be limited to the selected tyre characteristic 10; on the contrary, it is also possible while adapting one tyre characteristic to adapt one or more further tyre characteristics of one or more tyre characteristic maps 9 accordingly. Adaptation of further, so to speak "neighbouring", tyre characteristics can be performed on the basis of theoretical or empirical knowledge of tyre characteristic maps, for example.

One reason for this correction or adaptation can be that the properties of the tyres have changed over the period of operation of the vehicle, owing to a decrease in tread depth for example. A change in the properties of the tyre due to a tyre change is also detected and corrected by the simulation calculation. If the current adhesion 4 differs from the selected tyre characteristic, it is advantageously possible here for the correction or adaptation of the characteristic to be carried out approximately in normal driving states and to be carried out with high precision in the vicinity of the driving limit, this being explained in conjunction with Fig. 4.

The characteristic adaptor 6 outputs tyre characteristics which have been corrected or adapted for the wheels,

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these characteristics also being passed back to the characteristic-map memory 7 for storage. Since the adhesion limit 8 is described by the maxima of the individual tyre characteristics, it is thus known approximately when the vehicle is in a normal driving state. Insofar as the accuracy of characteristic adaptation is increased when the vehicle is approaching the driving limit, the adhesion limit is known with greater accuracy in the boundary zone.

Fig. 2 shows a table to explain in greater detail the procedure involved in roadway detection 5 using a bound method. In a bound method, the state of the roadway is not measured precisely but delimited by means of various pieces of information. For this purpose, information which allows conclusions to be drawn about the state of the roadway is gathered. The more information that is available, the more precisely the state of the roadway can be defined. Evaluating a single piece of information, it is possible for the state of the roadway to be delimited only very roughly at first. If further information is evaluated in addition, the delimitation becomes more and more precise, even if the individual pieces of information, considered on their own, allow only rough delimitation.

On the left-hand side of Fig. 2, there are lines listing information on the state of the roadway, it being possible for this information to stem from roadway sensors 2 or from the evaluation of the calculation using the driving-dynamics simulation model 3. This information preferably comprises at least three of the following types: air temperature, roadway temperature, optical or acoustic detection of snow, optical or acoustic detection of ice, optical or acoustic detection of water or optical or acoustic detection of a dry roadway. The particular pieces of information can, for example, be in the form of

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analogue measured variables, digital information (yes/no) or as a qualitative indication (deep, moderate, low).

The columns show, by way of example, various states of the roadway, which are assumed to be unknown and which are to be determined by the roadway detector 5. These states of the roadway can preferably include three or more of the following: dry, damp, wet, shallow water, deep water, snow, ice, loose underlying surface.

If the measurement of the roadway temperature supplies the information "very low temperature", for example, and the roadway sensor for detecting snow and ice supplies a positive signal and the evaluation of the initial slope of the circumferential-force/slip curve shows that the initial slope is shallow, the only possibility according to the pattern of crosses is that the roadway is covered in snow. This result is obtained even though a roadway sensor 2 that detects specifically only the covering of the roadway by snow is not used. This bound system is furthermore redundant to a certain extent since, at least in some cases, the results can simply be checked. If, for instance, the sensor for determining roadway temperature fails in the example described, the covering of the roadway by snow can be identified by means of the two remaining pieces of information.

Fig. 3 shows a tyre characteristic map 9 by way of example, the said map containing a plurality of tyre characteristics 10 for various states of the roadway. A tyre characteristic 10 is a curve in the tyre characteristic map 9, and can be used to represent the circumferential force U as a function of the slip s or the lateral force as a function of the slip angle. In general terms, a tyre characteristic map 9 is a diagram in which a number of tyre characteristics 10 for different parameters are illustrated. For example, the

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tyre characteristic map 9 can illustrate circumferential-force/slip or lateral-force/slip-angle curves for various wheel loads, all the other parameters being held constant. Another possibility, as in Fig. 3, is circumferential-force/slip curves for various roadway surfaces, for example.

Within the context of the invention, the state of the roadway and/or the wheel load are preferably taken into account as the parameters of the tyre characteristic 10 or tyre characteristic map 9. Further or different advantageous parameters may be the transverse acceleration, the longitudinal acceleration, the rotational speed of the wheels or the camber angle, for example.

It is advantageous if, when the system is first put into operation or after intentional resetting to initial values, for example, the tyre characteristic maps 9 contain a basic set of characteristics 10 which does not as yet cover all conceivable parameter combinations. The basic tyre characteristics form a basic tyre characteristic diagram in which tyre characteristics for a small number of states of the roadway and/or wheel loads, for example, are stored in simplified general form. When the system is first put into operation, only a small number of basic tyre characteristics can be stored for a small number of different tyre/roadway combinations. These characteristics apply to an average tyre and do not accurately represent the behaviour of the tyre actually fitted. Its actual behaviour depends, inter alia, on the type of tyre, the state of the tread, the tyre pressure and other parameters.

The basic characteristic maps are sufficient since a correction or adaptation of the characteristics 10 stored is carried out in the system according to the invention.

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The state of the roadway is taken into account during this process. It is furthermore also advantageous if the tyre characteristic maps 9 are supplemented by further tyre characteristics 10. Parameter combinations that are lacking can here initially be covered by interpolation, being replaced in the course of vehicle operation by their own tyre characteristics 10.

It is advantageous if provision is made for the tyre characteristic maps 9 to comprise at least three basic tyre characteristics or tyre characteristics 10 for the following states of the roadway: dry, damp, wet, shallow water, deep water, snow, ice, loose underlying surface. The effect of wheel load and the interaction between the circumferential and the lateral forces can be taken into account on the basis of empirical values, for example.

Since the actual behaviour of a tyre does not coincide precisely with the behaviour described by the basic characteristics, the tyre characteristics 10 and thus also the tyre characteristic maps 9 are adapted during operation, a change in tyre behaviour due, for example, to wear also being taken into account. As long as the operating states are normal, with comparatively low longitudinal and transverse accelerations in combination with comparatively low circumferential-force/slip and slip-angle values, an approximate adaptation of the tyre characteristics 10 can be performed as soon as a deviation between the current adhesion (in a kinematic state of the wheel) and the selected tyre characteristic is detected, and an approximate determination of the adhesion limit 8 can thus be carried out. This is possible even though the exact shape of the actual tyre characteristic 10 in the range of high circumferential-force/slip and slip-angle values, i.e. comparatively high circumferential and/or lateral forces, is not yet known.

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Fig. 4 illustrates how the adaptation of the tyre characteristics 10 and the determination of the adhesion limit 8, 8a are carried out accurately in the region of the driving limit of the vehicle in accordance with a particularly advantageous feature of the invention. This highly accurate adaptation takes place as soon as the vehicle approaches the driving limit and the current adhesion 4 and the kinematic state of the wheels possibly no longer match the selected tyre characteristic 10. As a result, the calculation of the adhesion limit 8 becomes more accurate as the vehicle approaches the driving limit.

The adaptation of the tyre characteristic 10 can generally be performed as soon as deviations between the calculated current operating point 11 and the tyre characteristic 10 originally selected from the characteristic-map memory 7 occur. In this context, the operating point 11 describes the driving state of a vehicle or a tyre with which a particular circumferential force U, a particular circumferential slip s, a particular lateral force and a particular slip angle can be associated. Within the context of the invention, the position of the operating point in a tyre characteristic map 9 or on a tyre characteristic 10 is not necessarily determined by measuring the circumferential force U and slip s or lateral force and slip angle directly, the said variables instead being derived from the driving-dynamics simulation model 3, the selection of the tyre characteristic 10 involving the roadway detector 5.

The initial region 12 of the tyre characteristic 10 can be regarded to a large extent as approximately linear. Particularly in the initial region, the adaptation of the tyre characteristic 10 or determination of the adhesion limit will be approximate.

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At higher slip values, i.e. in the vicinity of the approximately applicable adhesion limit 8a, which is determined by the maximum of the tyre characteristic 10 selected, the selected characteristic 10 leaves the linear region, however. In this region too, deviation of the selected characteristic 10 from the actually valid characteristic 14, from which the actual adhesion limit 8 can be determined, can be detected from the fact that the operating point 11 does not lie on the selected tyre characteristic 10 but deviates from it. In the nonlinear case, this is the case for operating points 11 which lie above the deviation point 13.

The deviation point 13 is the point on the selected tyre characteristic 10 from which the actually valid tyre characteristic deviates from the selected tyre characteristic 10 or from a linear shape in the direction of increasing slip or slip-angle values. The region from which the operating point 11 deviates from the tyre characteristic 10 or from a linear shape is indicated in Fig. 4 by an upward-pointing arrow.

A soon as the operating point 11 no longer lies on the selected tyre characteristic 10, the selected tyre characteristic 10 is corrected, giving a new, corrected, tyre characteristic 14. This adapted tyre characteristic 14 then deviates, for example, from the originally selected characteristic 10, likewise from the deviation point 13. The adaptation can take place approximately already in the linear initial region. The detection of a deviation in conjunction with exact adaptation of the tyre characteristic and determination of the adhesion limit is preferably possible when the linear initial region 12 has been exceeded. However, exact adaptation of the tyre characteristic and determination of the adhesion limit are possible not only in the immediate vicinity of the adhesion limit but are possible at a relatively early

stage in the wider vicinity of the adhesion limit.

Deviation of the operating point 11 from the selected tyre characteristic 10 or deviation of the tyre characteristic 10 from the linear initial region can be used for sliding correction of the characteristic, each deviation being used for a correction. However, in many embodiments it can also be expedient if a correction is only carried out when the deviation exceeds a particular threshold.

When a deviation is detected, the selected tyre characteristic 10 can be converted to a corrected tyre characteristic 14, it being possible for this to be accomplished using the theoretical or empirical knowledge of neighbouring tyre characteristics or of the fundamental behaviour of vehicle tyres. Since adaptation of the tyre characteristic 10 to give a corrected tyre characteristic 14 can be performed more accurately particularly when the vehicle is approaching the driving limit, the accuracy of determination of the adhesion limit 8 is increased in the region of the adhesion limit 8 or driving limit.

In this way, approximate adaptation of the tyre characteristic maps in operating situations involving comparatively low longitudinal and transverse accelerations and accurate adaptation of the tyre characteristics during each approach to the driving limit is possible, irrespective of whether the driving situation is critical or not. During normal driving operation, the current adhesion limit is estimated continuously in an approximate manner. When the vehicle approaches the limiting range, determination of the current adhesion limit becomes more accurate. This means that precise data are available as soon as an exact intervention in the handling behaviour becomes necessary.

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The invention provides reliable and accurate information on the current adhesion and the current adhesion limit before the adhesion limit has been reached. It is particularly advantageous here that not only the current adhesion limit but also the shape of the valid tyre characteristic is available to allow extrapolation of the vehicle behaviour and, in the event of a vehicle control operation, optimum quality of control.

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List of reference numerals

1 Driving-dynamics sensor
2 Roadway sensor
3 Driving-dynamics simulation model
4 Adhesion
5 Roadway detector
6 Characteristic adaptor
7 Characteristic-map memory
8 Adhesion limit
8a Adhesion limit of the uncorrected tyre characteristic
9 Tyre characteristic diagram
10 Tyre characteristic
11 Operating point
12 Initial region
13 Deviation point
14 Corrected tyre characteristic

U Circumferential force
s Slip

DaimlerChrysler AG
Stuttgart

Patent claims

1. Method for determining the adhesion (4) and/or the adhesion limit (8) of a tyre of a vehicle in motion, comprising
measuring the driving state of the vehicle by means of a plurality of driving-dynamics sensors (1),
determining the state of the roadway by means of at least one roadway sensor (2), which detects the state of the roadway, and
evaluating the data of the driving-dynamics sensors (1) and of the roadway sensor (2), a computer determining by means of a driving-dynamics simulation model (3) the kinematic state of the wheel and the adhesion (4) and, taking into account at least one stored tyre characteristic diagram (9) comprising tyre characteristics (10), the adhesion limit (8),
characterized in that, starting with an initial set of basic tyre characteristics, the tyre characteristics (10) are adapted in the course of operation to the current tyre behaviour.

2. Method according to Claim 1, characterized in that adaptation of the tyre characteristics (10) takes place when a deviation from a tyre characteristic (10) is detected on the basis of a comparison of the results from the driving-dynamics simulation model (3) and the determination of the state of the roadway.

3. Method according to Claim 1 or 2, characterized in that the state of the roadway is determined by means of a plurality of different roadway sensors (2), the

information derived from their signals being evaluated by means of a bound method for delimiting the state of the roadway.

4. Method according to one of the preceding claims, characterized in that the roadway sensors (2) include at least three of the following types: air temperature, roadway temperature, optical or acoustic detection of snow or ice or water or a dry roadway.

5. Method according to one of the preceding claims, characterized in that the tyre characteristic diagram (9) comprises tyre characteristics (10) in the form of circumferential-force/slip and/or lateral-force/slip-angle curves for particular states of the roadway and/or for different wheel loads.

6. Method according to one of the preceding claims, characterized in that the tyre characteristic diagram (9) comprises at least three basic tyre characteristics or tyre characteristics (10) for the following states of the roadway: dry, damp, wet, shallow water, deep water, snow, ice, loose underlying surface.

7. Method according to one of the preceding claims, characterized in that the tyre characteristic maps (9) comprise only a small total number of tyre characteristics (10), preferably less than 40, particularly preferably less than 20 tyre characteristics for determining the adhesion (4) and the adhesion limit (8).

8. Method according to one of the preceding claims, characterized in that a tyre characteristic diagram

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(9) is supplemented in the course of operation by tyre characteristics (10) for further states of the roadway.

9. Method according to one of the preceding claims, characterized in that, during the adaptation of one tyre characteristic (10), one or more further tyre characteristics of one or more tyre characteristic maps (9) is adapted accordingly.

10. Method according to one of the preceding claims, characterized in that the bound method takes into account information from the driving-dynamics simulation calculation.

11. Method according to one of the preceding claims, characterized in that the bound method takes account of the initial slope of the adhesion curve.

12. Method according to one of the preceding claims, characterized in that the adaptation of the tyre characteristics (10) is carried out in an approximate manner in the region of normal operating states of the vehicle and is carried out accurately in the region of the driving limit.

13. Method according to one of the preceding claims, characterized in that the determination of the adhesion limit (8) is carried out in an approximate manner in the region of normal operating states of the vehicle and is carried out accurately in the region of the driving limit.

14. Method according to Claim 12 or 13, characterized in that the accurate adaptation or determination is carried out when the linear initial region (12) of the selected tyre characteristic (10) has been

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exceeded.

15. Method according to Claim 12, 13 or 14, characterized in that the adaptation or determination is carried out when a calculated operating point (11) deviates from a selected tyre characteristic (10).

16. Method according to one of the preceding claims, characterized in that the driving-dynamics simulation model (3) is a real-time model, by means of which the computer calculates the current kinematic state of the wheel and/or the current adhesion (4) and/or the current adhesion limit (8) of the wheel in real time.

17. Method according to one of the preceding claims, characterized in that the determination of the adhesion (4) and/or the adhesion limit (8) takes account of driving-dynamics parameters which are derived from data measured by means of the driving-dynamics sensors (1).

18. Method according to one of the preceding claims, characterized in that the adhesion (4) and/or the adhesion limit (8) is/are determined for each axle.

19. Method according to one of the preceding claims, characterized in that the adhesion and/or the adhesion limit of the entire vehicle is determined by means of the particular adhesion values (4) and/or adhesion limits (8) of all the wheels.

20. Apparatus for carrying out a method for determining the adhesion (4) and/or the adhesion limit (8) of a tyre of a vehicle in motion according to one of the preceding claims, comprising

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a plurality of driving-dynamics sensors (1) for measuring the driving state of the vehicle,
at least one roadway sensor (2), which detects the state of the roadway, for determining the state of the roadway and
a computer for evaluating the data from the driving-dynamics sensors (1) and the roadway sensor (2), the said computer using a driving-dynamics simulation model (3) to determine the kinematic state of the wheel and the adhesion (4) and, taking into account at least one stored tyre characteristic diagram (9) comprising tyre characteristics (10), the adhesion limit (8),
characterized in that the apparatus is designed to adapt the tyre characteristics (10) to the current tyre behaviour in the course of operation, starting from an initial set of basic tyre characteristics.

21. Apparatus according to Claim 20, characterized in that a plurality of different roadway sensors (2) for determining the state of the roadway is provided, and the computer is designed to delimit the state of the roadway, taking into account the information derived from the signals of the roadway sensors and using a bound method.

22. Method according to one of Claims 1-3, characterized in that the roadway sensors detect not only typical wet states of the roadway, such as ice, snow and water, but also properties of the underlying surface, especially roughness, nature of the material and/or an intermediate medium such as, in particular, oil, leaves or sand.

23. Method according to Claim 22, characterized in that the tyre characteristic diagram (9) comprises basic characteristics or tyre characteristics (10) for

various wet states of the roadway and/or properties of the underlying surface.

24. Method according to one of Claims 1-5, characterized in that the tyre characteristic diagram (9) comprises tyre characteristics (10) in the form of circumferential-force/slip and/or lateral-force/slip-angle curves for different wheel speeds.

25. Method according to one of Claims 1-17, characterized in that the adhesion (4) and/or the adhesion limit (8) is/are determined for each track or for each individual wheel.

26. Method or apparatus according to one of the preceding claims, characterized in that a mathematical tyre model for generating the tyre characteristics is used to determine the adhesion and/or the adhesion limit instead of or as a supplement to a stored tyre characteristic diagram, the transition from one tyre characteristic to another being effected by changing one or more parameters of the tyre model.

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DaimlerChrysler AG
Stuttgart

Abstract

The invention proposes a method and an apparatus for determining the adhesion and/or adhesion limit of a tyre of a vehicle, in which the data from driving-dynamics sensors are evaluated by means of a driving-dynamics simulation model and in which the evaluation of the data from roadway sensors takes into account tyre characteristics which are adapted in the course of operation to the current tyre behaviour. To delimit the state of the roadway, the information from the roadway sensors is preferably evaluated by means of a bound method.

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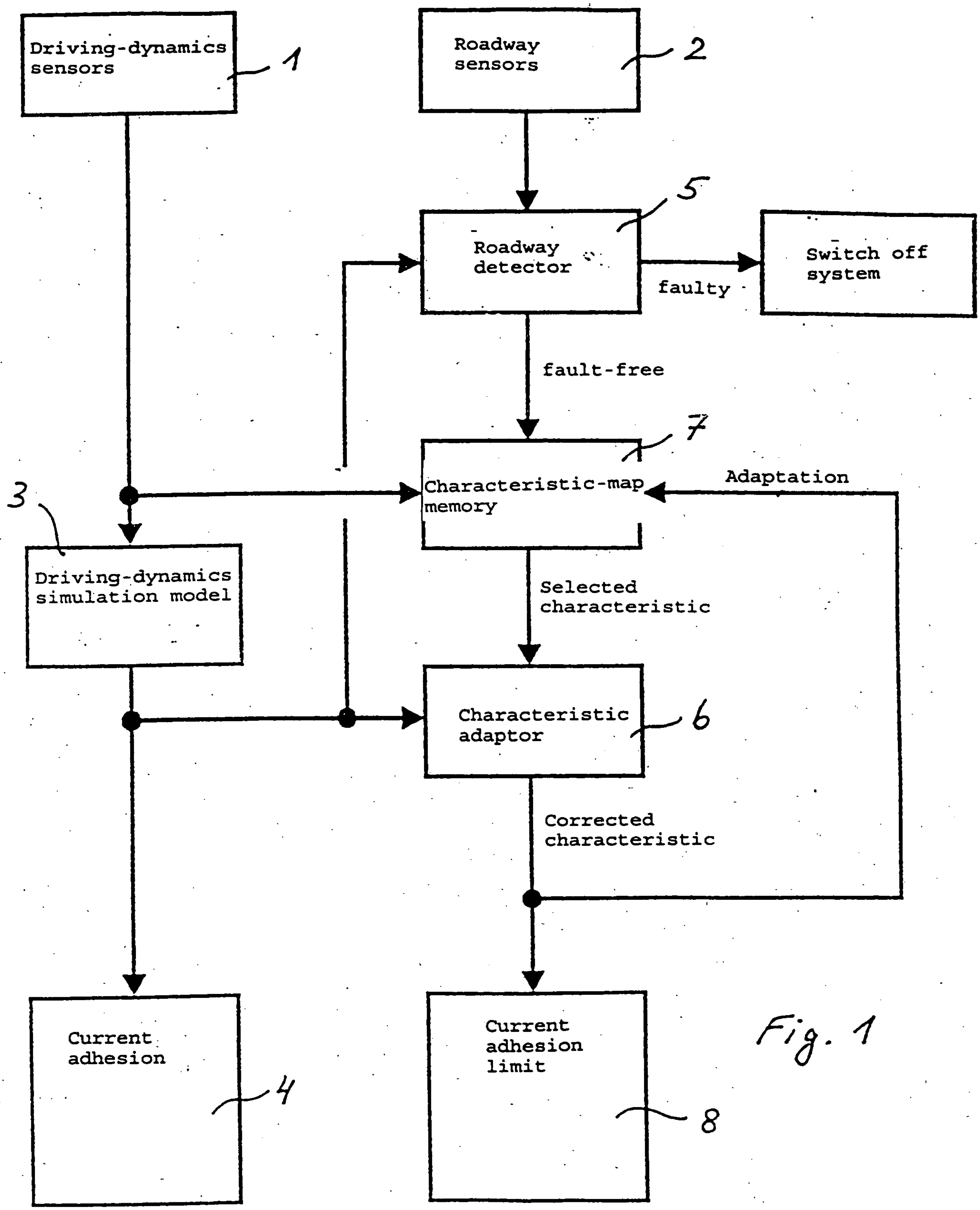

Fig. 1

X = Possible state of roadway

= Depending on the measured temperature, may apply to only one line

		icy roadway	snow-covered roadway	loose underlying surface	deep water	shallow water	dry roadway
Roadway temperature measurement (redundancy)	very low temp.	X	X	X			X
	slight frost	X	X	X	X	X	X
	over 0°C			X	X	X	X
Optical/acoustic method for detecting snow and ice		X	X				
Optical/acoustic method for detecting water					X		
Optical/acoustic method for detecting a dry roadway							X
Evaluation of the adhesion curves gentle initial slope			X	X	X		
⋮							

Fig. 2

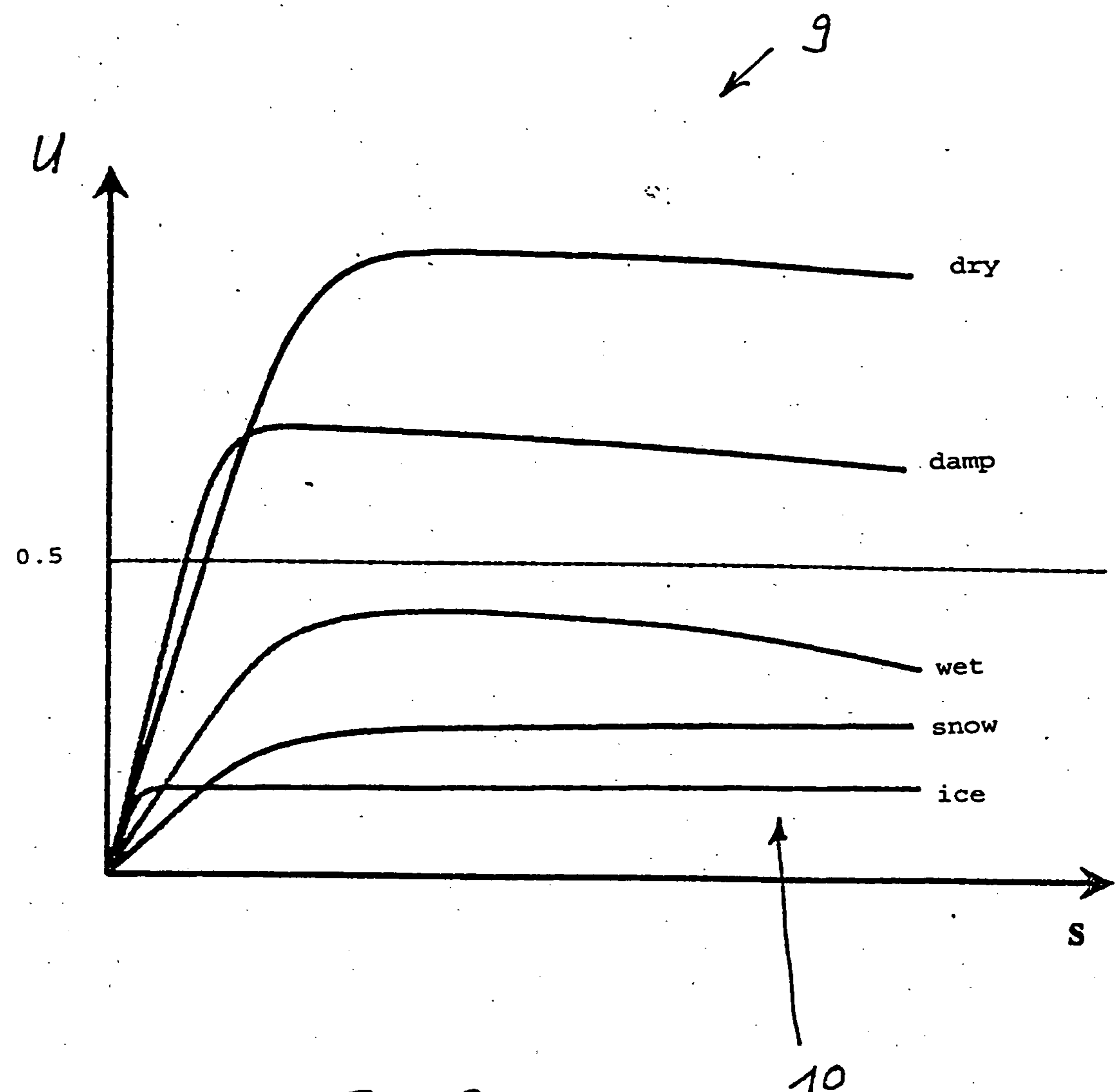

Fig. 3

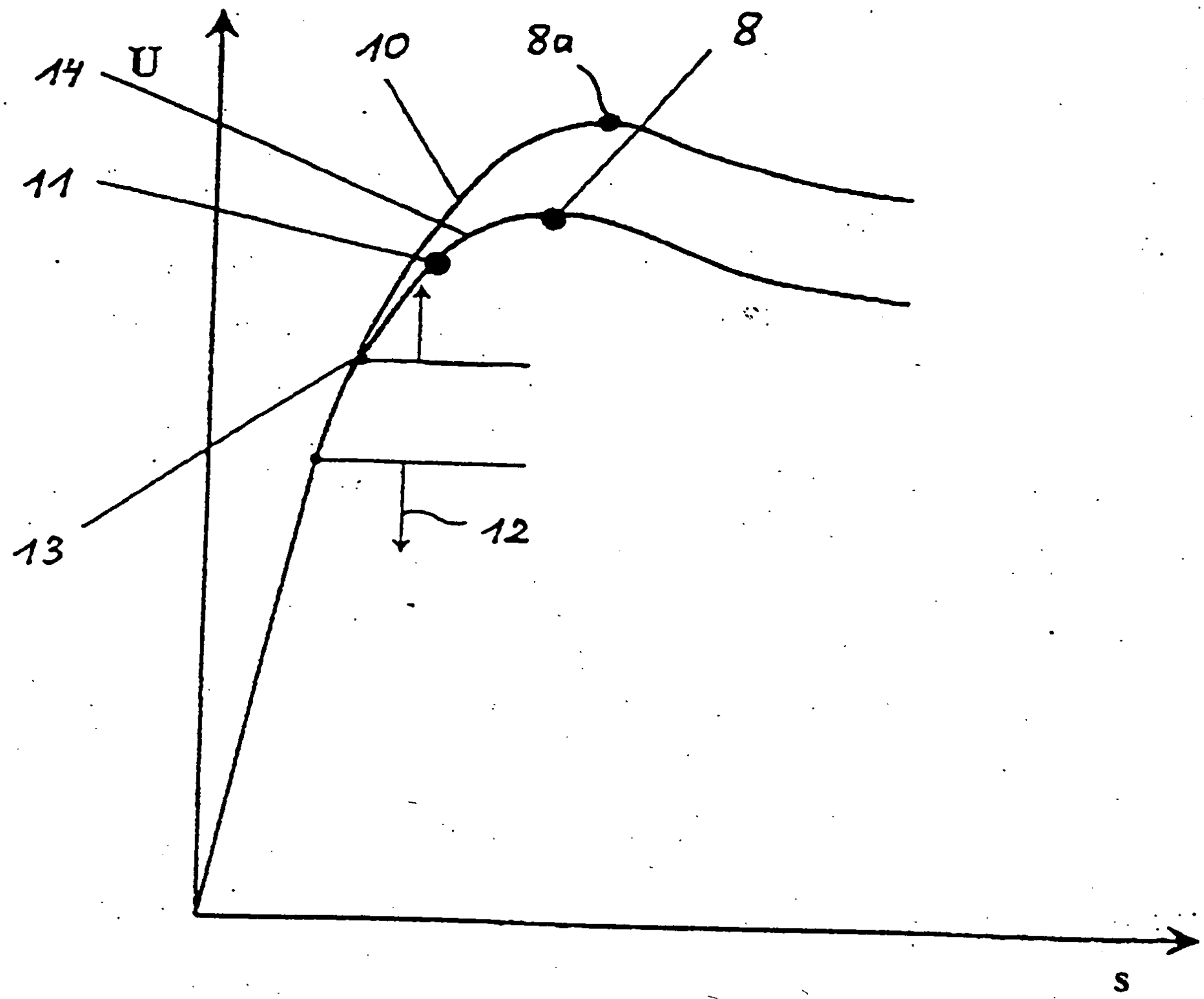

Fig. 4

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VERTRAG ÜBER DIE INTERNATIONALE ZUSAMMENARBEIT AUF DEM GEBIET DES PATENTWESENS

PCT

INTERNATIONALER RECHERCHENBERICHT

(Artikel 18 sowie Regeln 43 und 44 PCT)

Aktenzeichen des Anmelders oder Anwalts P033068/WO/1	**WEITERES VORGEHEN**	siehe Mitteilung über die Übermittlung des internationalen Recherchenberichts (Formblatt PCT/ISA/220) sowie, soweit zutreffend, nachstehender Punkt 5
Internationales Aktenzeichen PCT/EP 99/ 09347	Internationales Anmeldedatum *(Tag/Monat/Jahr)* 01/12/1999	(Frühestes) Prioritätsdatum *(Tag/Monat/Jahr)* 01/12/1998
Anmelder DAIMLERCHRYSLER AG et al.		

Dieser internationale Recherchenbericht wurde von der Internationalen Recherchenbehörde erstellt und wird dem Anmelder gemäß Artikel 18 übermittelt. Eine Kopie wird dem Internationalen Büro übermittelt.

Dieser internationale Recherchenbericht umfaßt insgesamt 3 Blätter.

[X] Darüber hinaus liegt ihm jeweils eine Kopie der in diesem Bericht genannten Unterlagen zum Stand der Technik bei.

1. **Grundlage des Berichts**

   a. Hinsichtlich der **Sprache** ist die internationale Recherche auf der Grundlage der internationalen Anmeldung in der Sprache durchgeführt worden, in der sie eingereicht wurde, sofern unter diesem Punkt nichts anderes angegeben ist.

   [ ] Die internationale Recherche ist auf der Grundlage einer bei der Behörde eingereichten Übersetzung der internationalen Anmeldung (Regel 23.1 b)) durchgeführt worden.

   b. Hinsichtlich der in der internationalen Anmeldung offenbarten **Nucleotid– und/oder Aminosäuresequenz** ist die internationale Recherche auf der Grundlage des Sequenzprotokolls durchgeführt worden, das

   [ ] in der internationalen Anmeldung in Schriftlicher Form enthalten ist.

   [ ] zusammen mit der internationalen Anmeldung in computerlesbarer Form eingereicht worden ist.

   [ ] bei der Behörde nachträglich in schriftlicher Form eingereicht worden ist.

   [ ] bei der Behörde nachträglich in computerlesbarer Form eingereicht worden ist.

   [ ] Die Erklärung, daß das nachträglich eingereichte schriftliche Sequenzprotokoll nicht über den Offenbarungsgehalt der internationalen Anmeldung im Anmeldezeitpunkt hinausgeht, wurde vorgelegt.

   [ ] Die Erklärung, daß die in computerlesbarer Form erfaßten Informationen dem schriftlichen Sequenzprotokoll entsprechen, wurde vorgelegt.

2. [ ] **Bestimmte Ansprüche haben sich als nicht recherchierbar erwiesen** (siehe Feld I).

3. [ ] **Mangelnde Einheitlichkeit der Erfindung** (siehe Feld II).

4. Hinsichtlich der **Bezeichnung der Erfindung**

   [X] wird der vom Anmelder eingereichte Wortlaut genehmigt.

   [ ] wurde der Wortlaut von der Behörde wie folgt festgesetzt:

5. Hinsichtlich der **Zusammenfassung**

   [X] wird der vom Anmelder eingereichte Wortlaut genehmigt.

   [ ] wurde der Wortlaut nach Regel 38.2b) in der in Feld III angegebenen Fassung von der Behörde festgesetzt. Der Anmelder kann der Behörde innerhalb eines Monats nach dem Datum der Absendung dieses internationalen Recherchenberichts eine Stellungnahme vorlegen.

6. Folgende Abbildung der **Zeichnungen** ist mit der Zusammenfassung zu veröffentlichen: Abb. Nr. 1

   [X] wie vom Anmelder vorgeschlagen

   [ ] keine der Abb.

   [ ] weil der Anmelder selbst keine Abbildung vorgeschlagen hat.

   [ ] weil diese Abbildung die Erfindung besser kennzeichnet.

INTERNATIONALER RECHERCHENBERICHT

Internationales Aktenzeichen
PCT/EP 99/09347

A. KLASSIFIZIERUNG DES ANMELDUNGSGEGENSTANDES
IPK 7 B60T8/00 G01N19/02

Nach der Internationalen Patentklassifikation (IPK) oder nach der nationalen Klassifikation und der IPK

B. RECHERCHIERTE GEBIETE

Recherchierter Mindestprüfstoff (Klassifikationssystem und Klassifikationssymbole)
IPK 7 B60T G01N

Recherchierte aber nicht zum Mindestprüfstoff gehörende Veröffentlichungen, soweit diese unter die recherchierten Gebiete fallen

Während der internationalen Recherche konsultierte elektronische Datenbank (Name der Datenbank und evtl. verwendete Suchbegriffe)

C. ALS WESENTLICH ANGESEHENE UNTERLAGEN

Kategorie°	Bezeichnung der Veröffentlichung, soweit erforderlich unter Angabe der in Betracht kommenden Teile	Betr. Anspruch Nr.
A	DE 37 41 247 C (DAIMLER BENZ AG) 24. Mai 1989 (1989-05-24) Spalte 4, Zeile 45 -Spalte 5, Zeile 19; Abbildung 5 ---	1,20
A	DE 44 30 108 A (BOSCH GMBH ROBERT) 29. Februar 1996 (1996-02-29) Spalte 4, Zeile 43 -Spalte 6, Zeile 10; Abbildung 4 ---	1,20
A	DE 42 18 034 A (PORSCHE AG) 9. Dezember 1993 (1993-12-09) Seite 3, Zeile 40 -Seite 18, Zeile 22; Abbildungen 1-24 --- -/--	1,20

[X] Weitere Veröffentlichungen sind der Fortsetzung von Feld C zu entnehmen

[X] Siehe Anhang Patentfamilie

° Besondere Kategorien von angegebenen Veröffentlichungen :

"A" Veröffentlichung, die den allgemeinen Stand der Technik definiert, aber nicht als besonders bedeutsam anzusehen ist

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"O" Veröffentlichung, die sich auf eine mündliche Offenbarung, eine Benutzung, eine Ausstellung oder andere Maßnahmen bezieht

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"&" Veröffentlichung, die Mitglied derselben Patentfamilie ist

Datum des Abschlusses der internationalen Recherche	Absendedatum des internationalen Recherchenberichts
9. März 2000	16/03/2000

Name und Postanschrift der Internationalen Recherchenbehörde	Bevollmächtigter Bediensteter
Europäisches Patentamt, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Blurton, M

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Formblatt PCT/ISA/210 (Blatt 2) (Juli 1992)

C.(Fortsetzung) ALS WESENTLICH ANGESEHENE UNTERLAGEN

Kategorie°	Bezeichnung der Veröffentlichung, soweit erforderlich unter Angabe der in Betracht kommenden Teile	Betr. Anspruch Nr.
A	DE 37 32 348 A (MESSERSCHMITT BOELKOW BLOHM) 13. April 1989 (1989-04-13) Spalte 1, Zeile 55 -Spalte 3, Zeile 6; Abbildung 1 ---	1,20
A	DE 42 00 997 A (STEYR DAIMLER PUCH AG) 22. Juli 1993 (1993-07-22) Spalte 4, Zeile 45 -Spalte 8, Zeile 38; Abbildungen 1-7 -----	1,20

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/EP 99/09347

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